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COMMENT ON THE LIGHT-HEAVY MAJORANA NEUTRINO MECHANISM
IN NO-NEUTRINO DOUBLE BETA DECAY

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ABSTRACT

We review the cancellation mechanism between light and heavy neutrinos in -neutrino double beta decay, and the limits on the mass and mixing angle for e heavy neutrino. We emphasize that the effective mass for no-neutrino double ta decay varies with atomic weight, being heavier the lighter the parent nu-eus. A search for double beta decay in ^{48}Ca will be an excellent test of this chanism.

As an alternative to what have become known as "Pseudo-Dirac" neutrinos[1], Halprin, Petcov and I[2] have proposed the "light-heavy" mechanism for cancellations in double beta decay. The idea is inspired by the "see-saw" mass matrix of Gell-Mann, Ramond, and Slansky[3], and by an earlier observation that experimental limits on double beta decay lifetimes yield <u>lower</u> limits on "heavy" neutrino masses[4], as well as <u>upper</u> limits on "light" neutrino masses. Thus we proposed that in the amplitude for no-neutrino double beta decay, the exchange of a light neutrino, with mass a few times 10 ev, is almost cancelled by the exchange of a heavy neutrino, with opposite CP and mass anywhere from a few times 10 Mev to 5 Gev or more. In our case, both neutrinos must have the same helicity if they are to interfere coherently with one another.

The exchange of a light neutrino between two nucleons inside a nucleus gives rise to an effective Coulomb-like potential in the nuclear matrix element, whereas the exchange of a heavy neutrino gives rise to an effective Yukawa-like potential[4]. Therefore the "effective mass" in the no-neutrino decay amplitude has the form[2]

$$M_{\beta\beta} = |M_\ell \cos^2 \theta - F(M_h,A)M_h \sin^2 \theta| \tag{1}$$

where M_ℓ and M_h are the light and heavy masses respectively, and θ is the mixing angle between them. The function $F(M_h,A)$ is the ratio of the Yukawa-like and Coulomb-like potentials,

$$F(M_h,A) = \langle \exp(-M_h r)/r \rangle \Big/ \langle 1/r \rangle \tag{2}$$

and the argument A is inserted to emphasize that the value and functional form of F varies from one nucleus to another. Its value and form also depends upon the two-nucleon correlation functions used to evaluate the numerator and denominator in eq. (2).

We have found, in our investigations, that this mechanism gives us two general, qualitative results[2]. One is an <u>upper</u> bound on the mass of the heavy neutrino: M_h cannot be so large in eq. (2) that there is virtually no cancellation in eq. (1). The other is that the effective double beta decay mass, $M_{\beta\beta}$, varies with atomic mass, the general tendency being for $M_{\beta\beta}$ to become larger as the parent nucleus becomes lighter

Exactly what the upper bound on M_h is, or what the values of $M_{\beta\beta}$ are, can depend sensitively upon the two-nucleon correlation function being used. In a model with a hard core at 0.5 fermi[2], we have obtained a bound of 3.5 Gev, while in another model[5] the bound is only 500 Mev. The light neutrino mass M_ℓ falls in the ITEP-80 range[6] in both cases, and $M_{\beta\beta}$ is bounded by the latest Tellurium ratio results[7]. As for the effective double beta decay mass for lighter nuclei, we find similar results in both models:

$$5 \text{ ev} < {}^{82}\langle M_{\beta\beta}\rangle < 16 \text{ ev}$$
$$13 \text{ ev} < {}^{48}\langle M_{\beta\beta}\rangle < 43 \text{ ev} \tag{3a}$$

for the first model, and

$$^{82}\langle M_{\beta\beta}\rangle \simeq 18 \text{ ev}$$
$$^{48}\langle M_{\beta\beta}\rangle \simeq 45 \text{ ev} \tag{3b}$$

for the second. In eq. (3) the superscripts 82 and 48 stand for the parent isotopes ^{82}Se and ^{48}Ca.

Besides an upper bound on M_h, one can also use this analysis to mark out an "allowed" region in that part of the $\sin^2\theta$ - M_h plane for which $\sin^2\theta$ is small. From eq. (1), one finds that for small mixing angles, the allowed region is determined by the condition:

$$(M_\ell + M_{\beta\beta}) > M_h \, F\,(M_h, A) \sin^2\theta > (M_\ell - M_{\beta\beta}) \tag{4}$$

For illustrative purposes we take $M_\ell = 30$ ev, $M_{\beta\beta} = 5$ ev, and A = 130, corresponding to Tellurium. In the first model mentioned above, the limit in eq. (4) takes the form:

$$35 > 1.4 \times 10^6 \sin^2\theta \exp\,[-M_h/400] > 25 \tag{5}$$

where M_h is measured in Mev. Numerical values are given in Table I:

Table I: Mass ranges versus $\sin^2\theta$ for Model I

$\sin^2\theta$	10^{-2}	10^{-4}	3×10^{-5}
M_h	2.50 > M_h > 2.36 Gev	674 > M_h 540 Mev	197 > M_h > 64 Mev

As long as the heavy neutrino is not identified with ν_τ, the final column will not be in conflict with the CHARM experiment[8].

In the second model, the bounds are given by

$$35 \text{ ev} > M_h \sin^2\theta \exp\,(-M_h/33) > 25 \text{ ev} \tag{6}$$

where again M_h is measured in Mev. The corresponding numerical ranges are now:

Table II: Mass ranges versus $\sin^2\theta$ for Model II

$\sin^2\theta$	10^{-2}	10^{-4}	3×10^{-6}
M_h (Mev)	395 > M_h > 383	224 > M_h > 211	70 > M_h > 43

The mass values in Table II are significantly smaller than the corresponding ones in Table I, and the final column is no longer in conflict with the CHARM experiment. Thus it is possible to identify the heavy neutrino with ν_τ in this second model.

The crucial test of these ideas is the variation of $M_{\beta\beta}$ with atomic mass. It is therefore necessary to study double beta decay in a variety of isotopes to determine whether such a variation does or does not occur in nature. Of special interest is the decay of ^{48}Ca for which one expects the largest value of $M_{\beta\beta}$ (see eq. (3)), and for which there is general agreement regarding the magnitude of the matrix element. We therefore urge that a new effort be made to search for the no-neutrino double beta decay of ^{48}Ca.

References

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